Montana's Approach to Developing Numeric Nutrient Standards for Wadeable Streams and Rivers

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Presentation for WERF Nutrients Stakeholder Meeting

July 2, 2009

Science: How were the Criteria Derived?

Nutrient criteria development for wadeable streams across a large, diverse state required 3 major parts:

1) Identification of appropriate geographic zones in which specific nutrient criteria (e.g., total P, total N) would apply

2) Understanding of cause-effect (i.e., stressor-response) relationships between nutrients and beneficial uses (e.g., fisheries, recreation, aquatic life)
   - Requires determination of "harm to use"

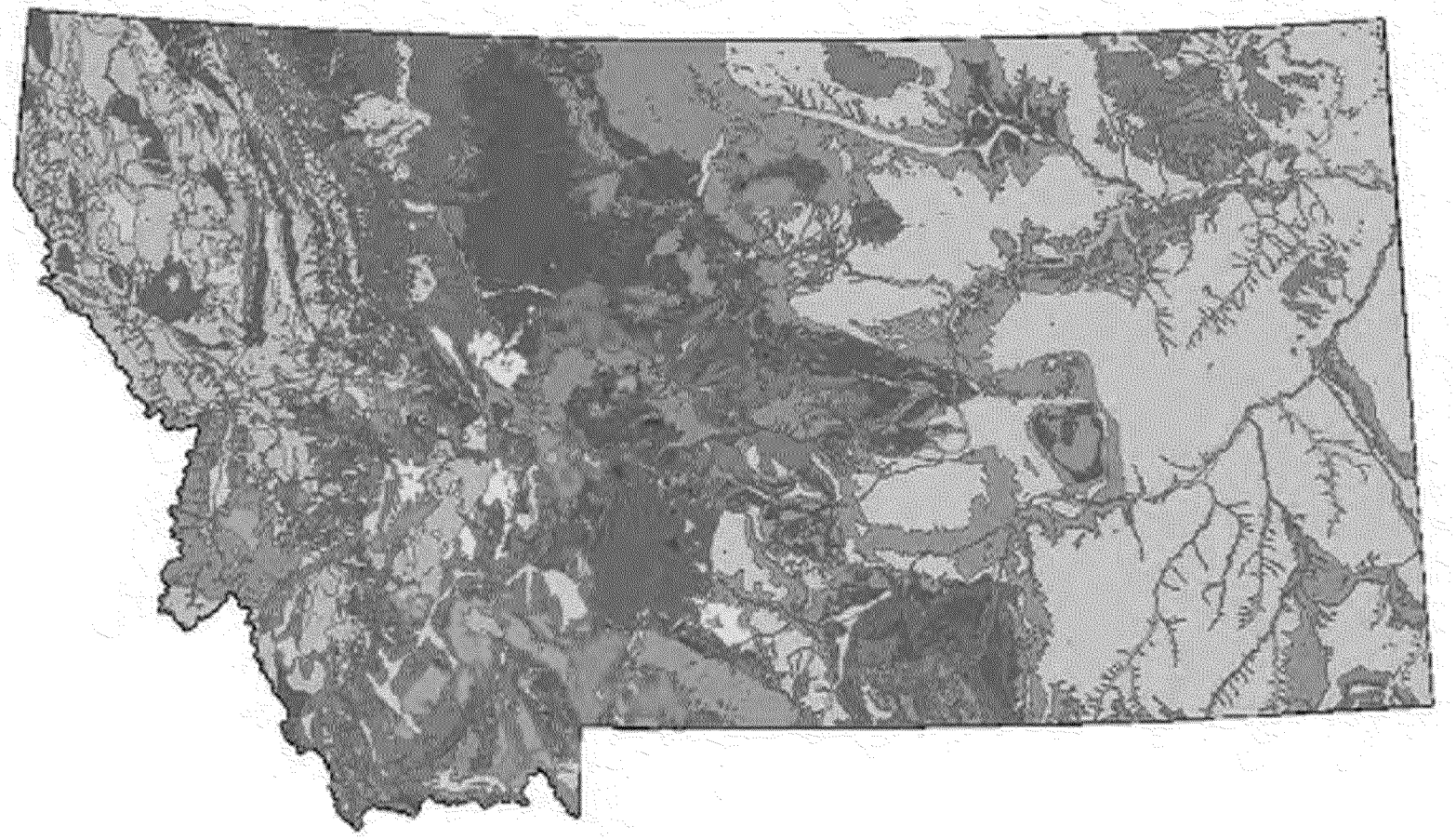
3) Water quality data from reference sites

Science: (1) Identifying an Appropriate Geospatial Framework

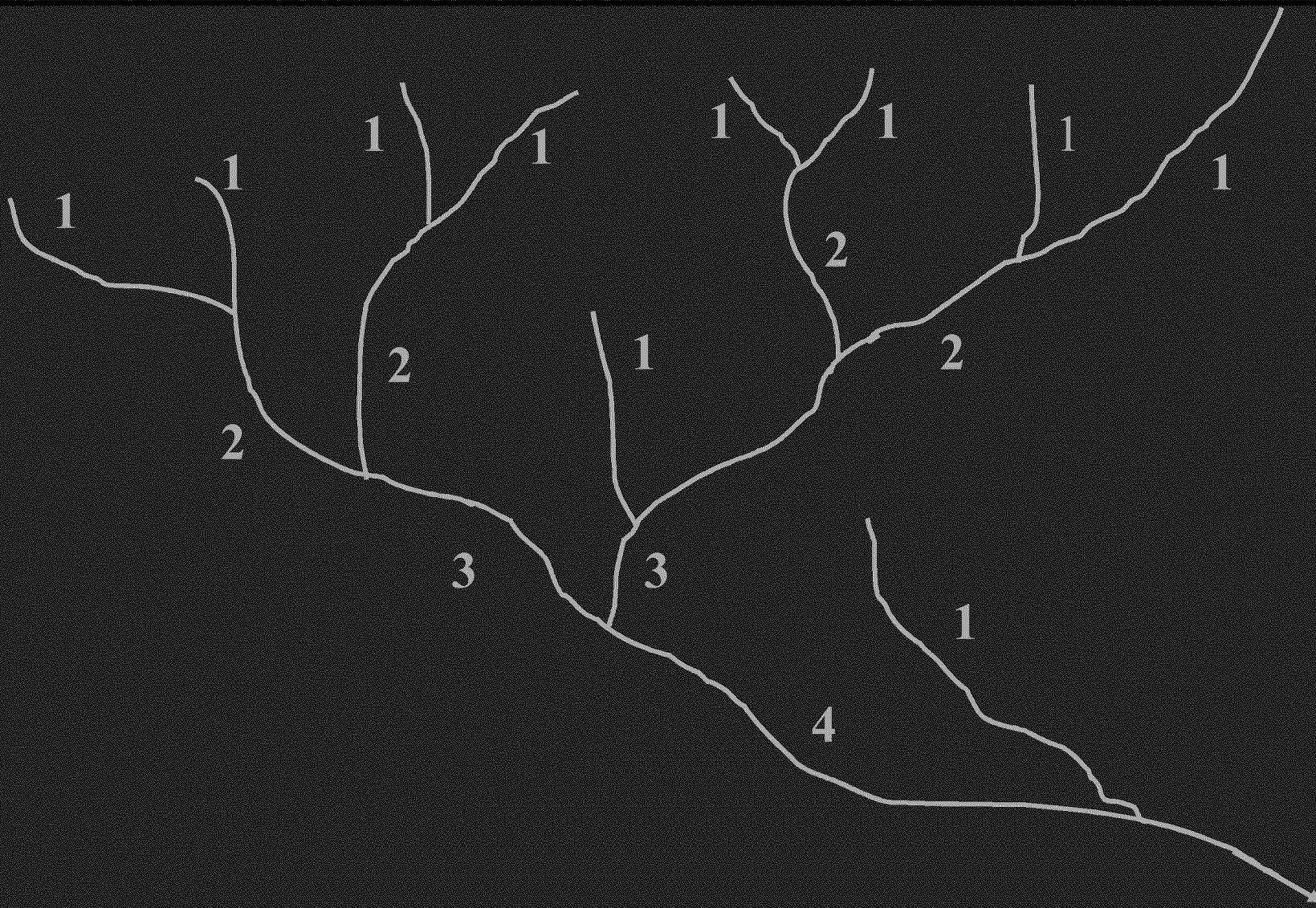
- We tested three mapping systems as candidates for "nutrient zones"
  - Ecoregions
  - Lithology
  - Strahler stream order
  - Used non-parametric and parametric tests to analyze
    - Kruskal Wallis Test
    - ANOVA
- Best geospatial framework maximizes the variance between nutrient zones, minimizes variance within zones

Level III Ecoregions of MT (Woods et al. 2002)

USGS Geology Map of Montana (1955)



Strahler Stream Order



Science: (1) Conclusions about the Geospatial Frameworks

- Level III & IV ecoregions worked better than lithology and stream order, in terms of significantly explaining variation in nutrient concentrations, practicality of application

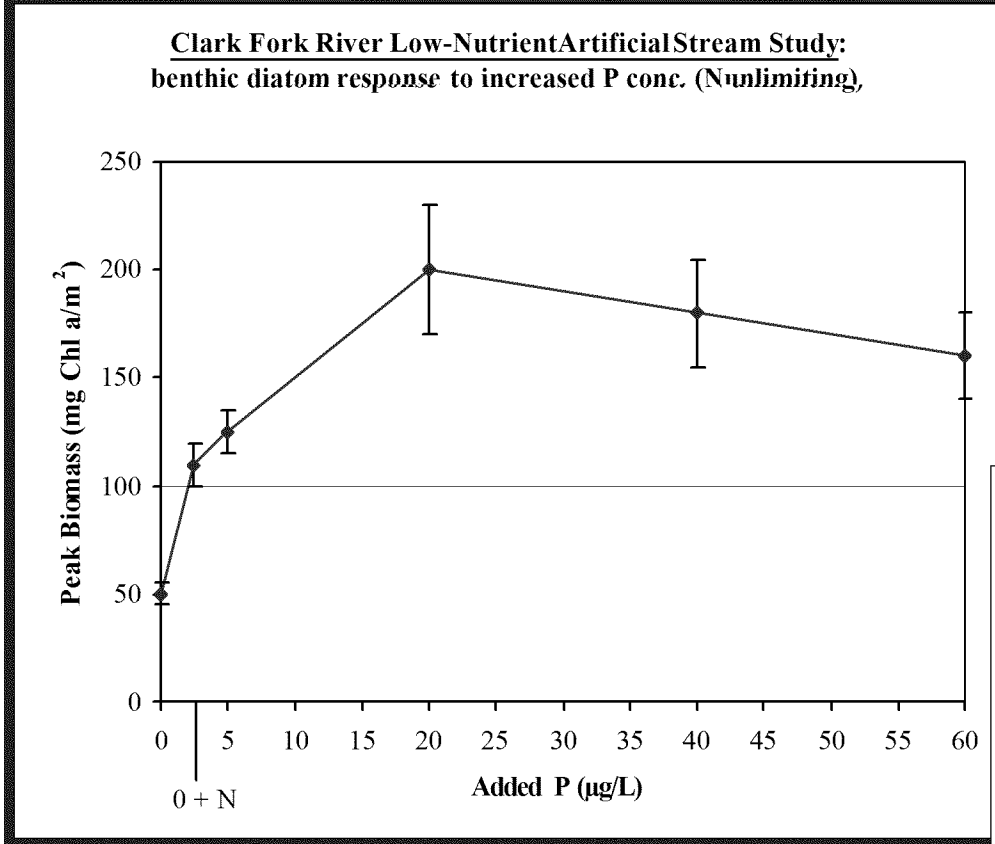
- Ecoregions explained sufficient spatial variability in nutrients to be used as a basis to establish criteria across Montana
  - Typically 60-78% of variation in reference stream data, depending on test type, nutrient, season

Science: (2) Stressor-response, Harm-to-use

- Stressor-response studies (e.g., TN *vs.* dissolved oxygen concentrations)

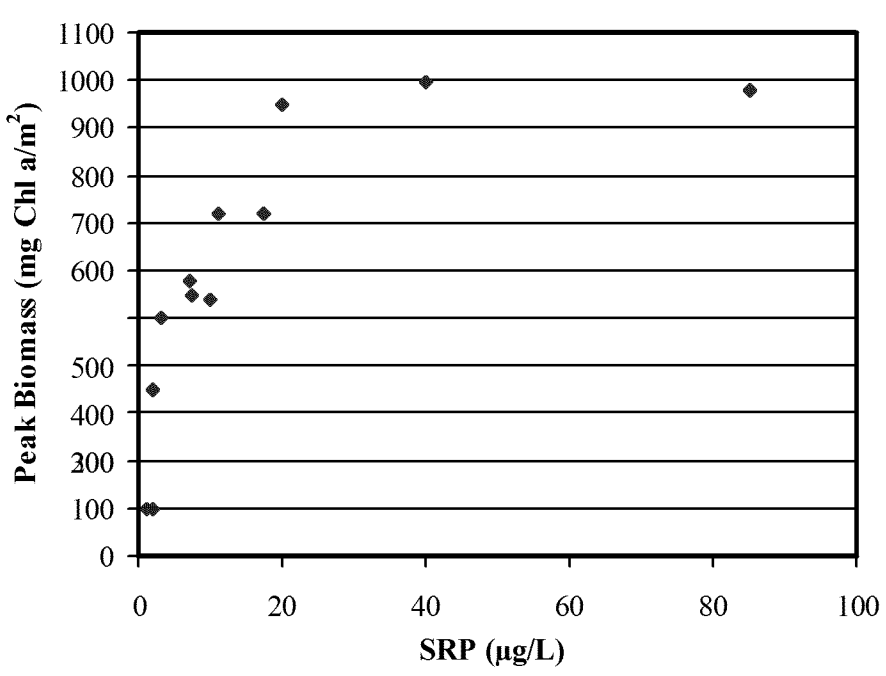
- Harm-to-use thresholds: Identifying the point where nutrient concentrations begin to impact sensitive beneficial uses
  - *Recreation* (nuisance algae public-opinion survey)
  - *Fish & aquatic life*

Science: (2) Example Stressor-response Studies



Redrawn from Watson (1990)

Redrawn from Welch (1992)



MT DEQ also reviewed correlation and stream nutrient-dosing studies

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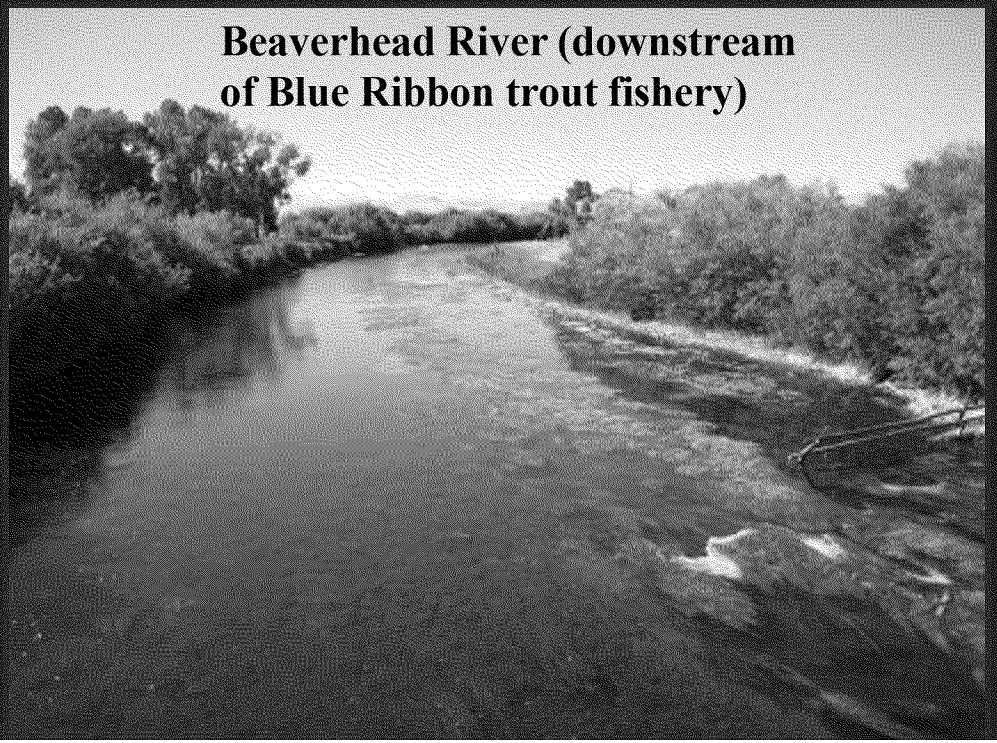
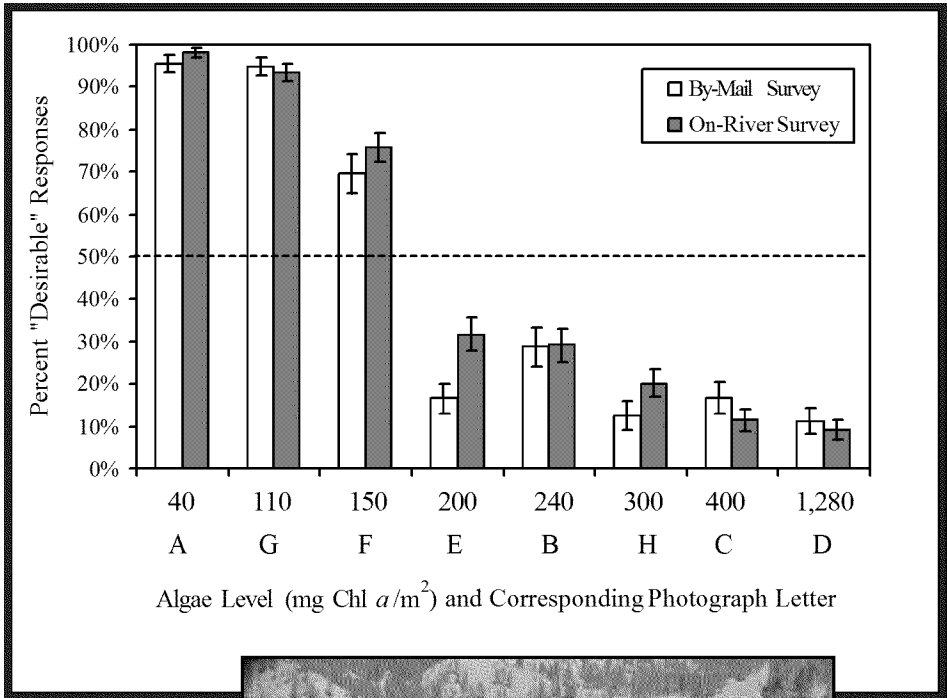


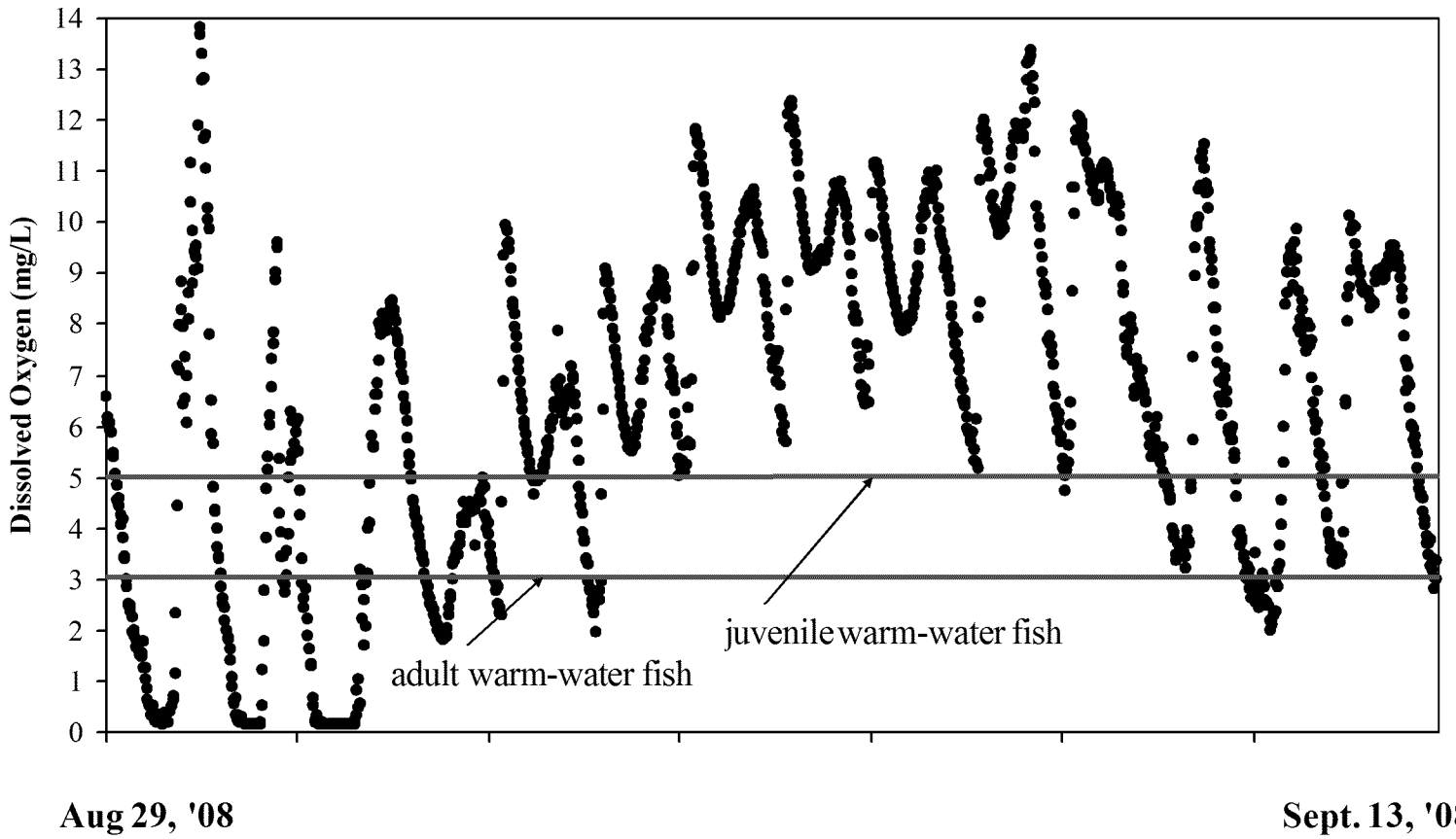
Nuisance algal growth



Science: (2) Harm to Use: Recreation Threshold

Suplee, Watson, Teply & McKee, 2009. How Green is too Green? Public Opinion of what Constitutes Undesirable Algae Levels in Streams. *Journal of the American Water Resources Association* **43**: 123-140

Science: (2) Harm-to-Use: Aquatic Life Thresholds



In eastern MT prairie streams, nutrient criteria are being set to maintain dissolved oxygen levels at state standards (fish, aquatic life)

Science: (2) Harm-to-Use: Aquatic Life Thresholds

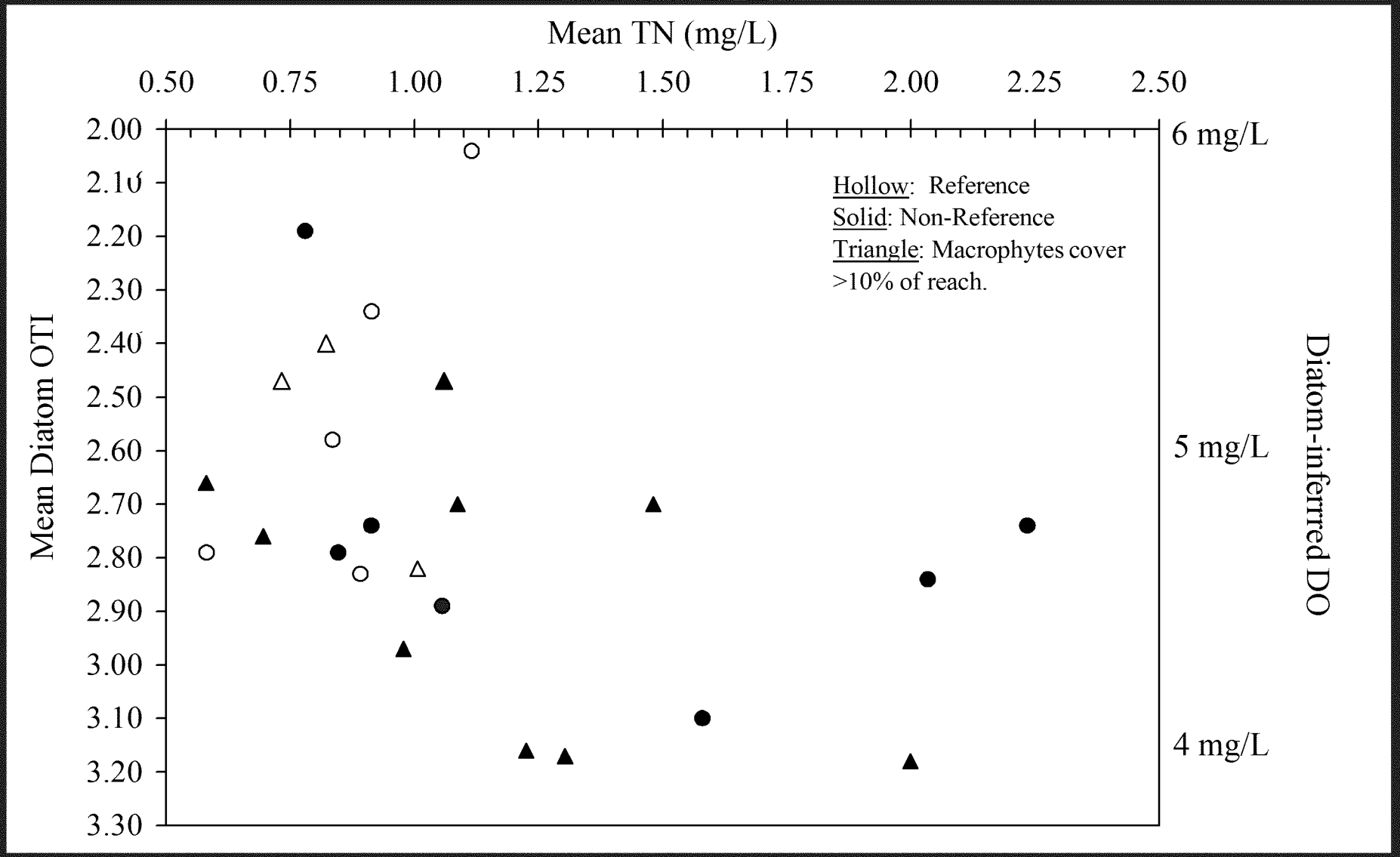


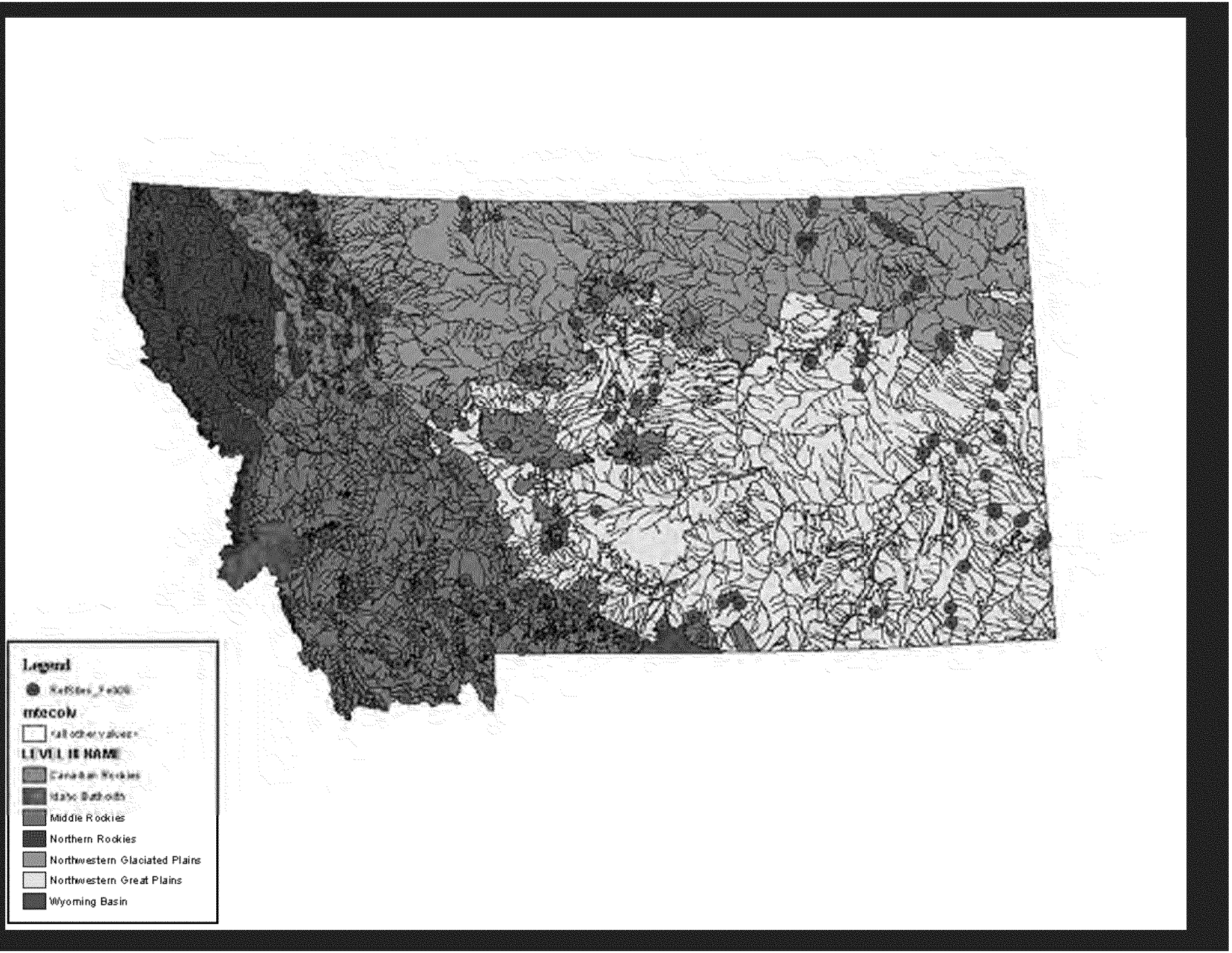
Figure 3.1. Scatterplot of Diatom OTI *vs.* Total N Concentrations, All Sites. Diatom-inferred dissolved oxygen (DO) was calculated based on a DO at saturation of 8 mg/L.

Science: (3) Reference Stream Sites

Reference Streams: Nutrient concentration data from reference streams — which in most cases don't have heavy benthic algal growth or low dissolved-oxygen — were compiled for each ecoregion

Eastern MT prairie-stream reference site

Western MT reference stream site


Legend
mtecon
LEVEL III NAME
Middle Rockies
Northern Rockies
Northwestern Glaciated Plains
Northwestern Great Plains
Wyoming Basin

Science: Comparing Stressor-response Study Results to Reference Data - Why do it?

- Individual stressor-response studies are geographically limited, each has its own statistical uncertainties

- Individually, each stressor-response study is suggestive; collectively, they become far more conclusive
  - Akin to a "strength-of-evidence" approach
  - Comparing results from a regional stressor-response study to reference data from its corresponding ecoregion provides a means to tie various studies together

- Helps assures that criteria for any region are not overly stringent or insufficiently protective

Science: Linking Stressor-response Studies & Reference Data

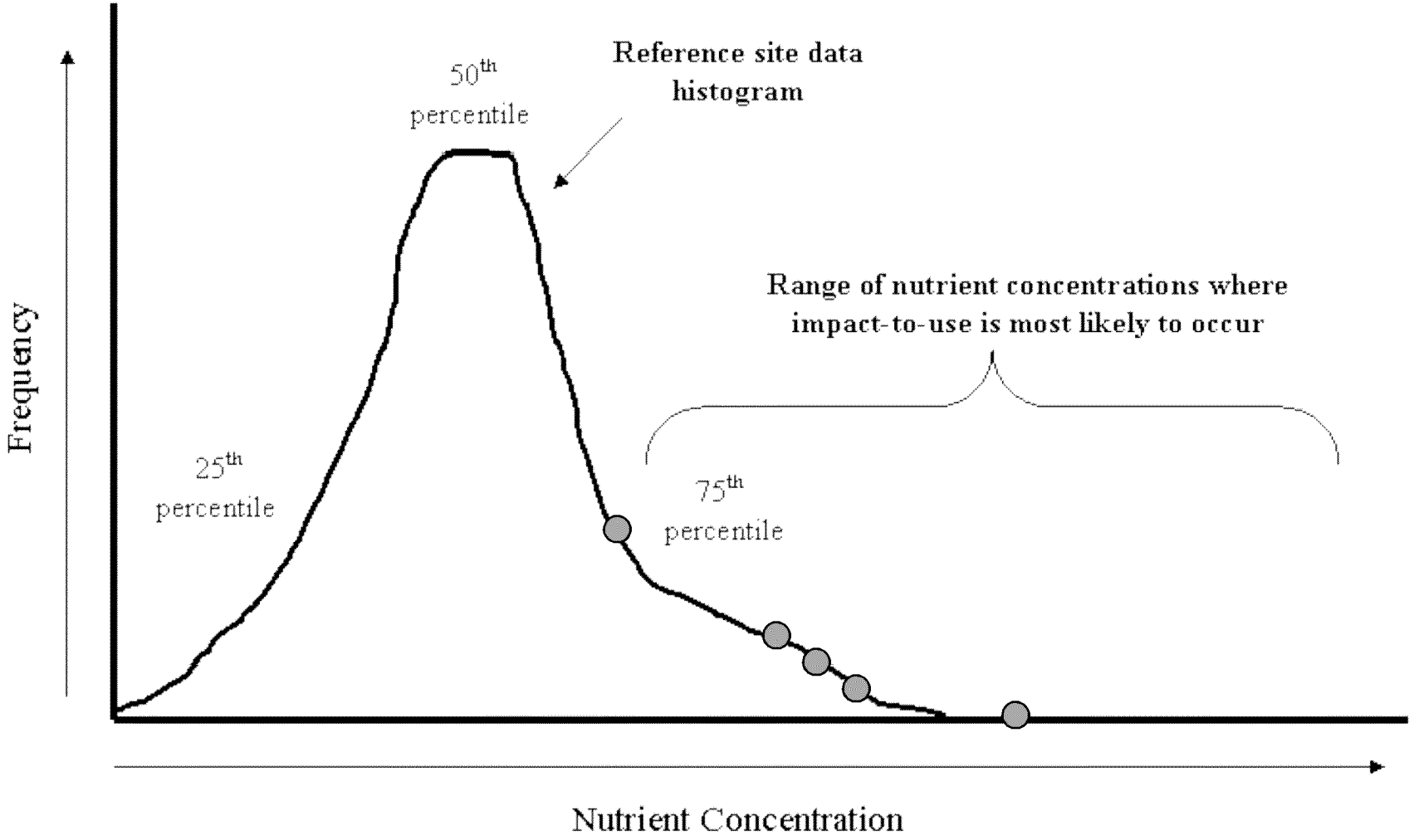


Figure 6.2. Conceptual Diagram Showing a Nutrient Concentration Histogram for Reference Sites. The figure shows where along the x-axis, relative to the histogram, nutrient concentrations likely to impact beneficial water uses would be expected to be found.

Science: Linking Stressor-response Studies & Reference Data

			Reference Stream Sites				
Stressor-response Study	Nutrient	Stressor-response Study Nutrient Concentration (mg/L)	Season of Application	**Level III Ecoregion**	# Samples in During Summer Growing Season	**Percentile in Reference Distribution Matching Stressor-response Study Concentration**	Sensitive Benefical Use Nutrient Concentration Applies To:
Welch *et al*. (1989)	SRP	0.01	Growing (summer)	**Northern Rockies**	75	**94th**	Recreation
Watson *et al.* (1990)	SRP	0.011	Growing (summer)	**Middle Rockies**	211	**87th**	Recreation
Sosiak, A. (2002)	TP	0.018	Growing (summer)	**Canadian Rockies**	68	**97th**	Recreation
Bowman *et al.* (2007)	SRP	0.009	Growing (summer)	**Canadian Rockies**	59	**108^{th*}**	Recreation
Suplee *et al*. (2008) Technical Document (Appendix A)	TN	1.12	Growing (summer)	**Northwestern Glaciated Plains**	59	**70th**	Fish & Aquatic Life
					Mean:	**91**	
					Median:	**94**	
					CV (%):	**15**	

* Interpolated from dataset.

Also see Suplee, M.W., Varghese, A., and J. Cleland, 2007. Developing Nutrient Criteria for Streams: An Evaluation of the Frequency Distribution Method. *Journal of the American Water Resources Association* 43: 453-472.

Science: Comparison of Some of Montana's Criteria To Other Studies/Criteria in Temperate Streams

Source	Location	Concentration Shown Would:	Nutrient (mg/L) Total N	Nutrient (mg/L) Total P
***Draft* DEQ Values**	**Middle Rockies Ecoregion, Montana**	**Prevent nuisance algal growth**	**0.320**	**0.048**
Perrin *et al.* (1987)	British Columbia, Canada	Prevent nuisance algal growth	0.4	0.02
Miltner & Rankin (1998)	Ohio	Protect fish communuties	n/a	0.06
Chételat *et al.* (1999)	Ontario & Quebec, Canada	Prevent nuisance algal growth	n/a	0.04 to 0.07
Wang *et al.* (2007)	Wisconsin	Protect fish and macroinvertebrate communities	0.99	0.073
Dodds *et al.* (2006)	North American, Austrailian, New Zealand and European temperate streams	Prevent nuisance algal growth	0.578	0.080
ANZECC & ARMCANZ Trigger Values (2000)	New Zealand (upland rivers)	Prevent nuisance algal growth & cyanobacterial blooms	0.295	0.026
ANZECC & ARMCANZ Trigger Values (2000)	Australia (upland rivers)	Prevent nuisance algal growth & cyanobacterial blooms	0.250	0.02

Science: Allowable Exceedence Rate for the Criteria (i.e., frequency)

1. Criteria not "no sample shall exceed"
2. EPA recommends 10-25% exceedence rate for most types of criteria (SOURCE: 303[d] listing guidance)
3. Analysis of a 9-year dataset on Clark Fork River (river has numeric nutrient criteria in place)
   - Some sites consistently have nuisance algae levels, others rarely
   - ~54% of N and P samples from sites with nuisance algae exceed criteria
   - ~6% of N and P samples from sites without nuisance algae exceed criteria
   - 25% exceedence appears to be a threshold. Keeping algae below nuisance levels appears to become untenable at higher exceedences

- Recommending a 20% allowable exceedence rate to accompany the numeric nutrient criteria, for 303(d) assessment purposes
- Consistent with the fact that, collectively, reference sites have a ~10% criteria exceedence rate
  - constrains false positive rate

Science: Coming Full Circle

- Will test draft criteria in a whole-stream nutrient dosing study
  - Dosing a reference stream with N, P
  - BACI design
    - (1) Control reach, (2) experimental reach @ criteria, (3) experimental reach @ saturation
- About the only way to directly test affects of nutrients on streams at the landscape scale

"Study – formulate criteria – test – repeat"

Work on Other Waterbody Types

- Lakes

- Large Rivers: Pilot effort on lower Yellowstone River using a water quality model (QUAL2K) - nearing completion

Summary of Key Points

- Ecoregions (level III and IV) are a practical mapping system for creating nutrient zones
- Linking together information from stressor-response studies and reference sites greatly increases confidence in criteria
- Montana wadeable stream nutrient standards will only apply for about 3 months each year (i.e., summer)
  - Except where downstream terminal waterbodies would drive the stream criteria